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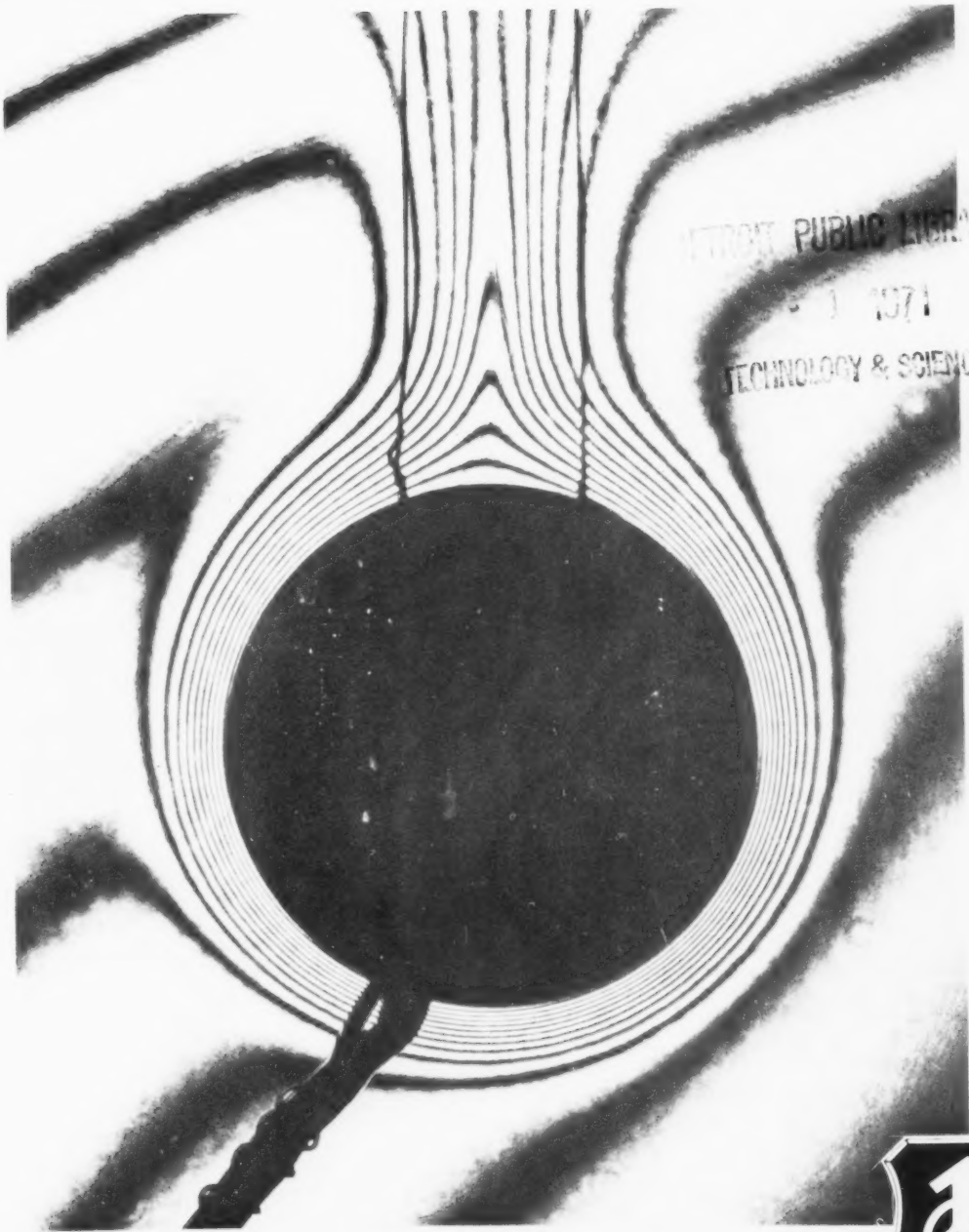
AIR FORCE

research review

Number 3 November ★ December 1970



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AIR FORCE research review

NUMBER 3 NOVEMBER ★ DECEMBER 1970

ON THE COVER

HOLOGRAPHIC INTERFEROGRAM of a uniformly heated horizontal right-circular cylinder. For further details on this photograph, see the discussion of figure 3 in the article entitled "Flow Studies With Pulsed Laser Holography."

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ETHEL GAMER, *Editor*

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chemical laser research

Dr. Donald L. Ball, Directorate of Chemical Sciences, AFOSR

Enormous strides in recent years in the science and technology of lasers have been paced by worldwide vigorous basic and applied research programs. One such program, supported by the Air Force Office of Scientific Research at the University of California at Berkeley, has produced a variety known as the chemical laser. In addition to their present and potential defense applications, chemical lasers are being used to unravel complex microscopic events of chemical kinetics. The research is under the direction of Dr. George C. Pimentel, who has observed laser emission from 36 different reactions of five distinct types, as announced in May 1969. In view of this progress with the chemical laser as a research tool, it is important to note the mechanism of the chemical laser and its special characteristics.

Whether solid, liquid, or gas, a laser emits monochromatic, directional, coherent, and intense radiation following an inversion in the normal population of energy states. This inversion, i.e., occupation of higher energy states than the most stable, requires an input of energy (or "pumping"). The situation is given schematically as follows:

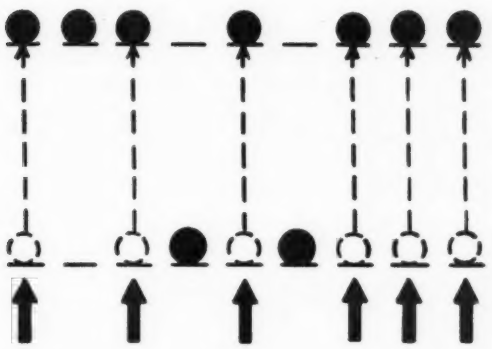

Figure 1. Energy input.

Light photons of appropriate energy (equal to the difference between the levels) can stimulate relaxation to the lower energy state again with the additional emission of photons of the very same energy (wavelength). This is the basis of laser action and the origin of the word (the acronym was formed from *l*ight *a*mplification by *s*timulated *e*mission of *r*adiation). It is also necessary, of course, that the active material be suitably contained in a resonant cavity–bounded by reflective mirrors. After the radiation intensity has built up (following multiple reflections), some means is provided to allow emergence of the laser light from the cavity.

Lasers are available with a variety of emission frequencies. The energy levels, which provide the basis for "lasing," can be differences in electronic states, but more commonly they are differences in vibrational energy. The associated transitions are called vibrational/rotational transitions. Ordinarily, a change in vibrational energy is accompanied by a change in rotational energy. For example, a unit decrease in the vibrational quantum number, V, (which labels this energy state) may be associated with a unit *increase* in rotational quantum number, J. This transition–or the reverse associated with light absorption rather than emission–is responsible for the familiar "P branch" in infrared spectra. The "Q and R branches" are due to $\Delta J = 0$ and $\Delta J = +1$, respectively, with $\Delta V = +1$ (on absorption). The transition energy increases, of course, in the sequence P,Q,R. Depending on the nature of the molecular system (and corresponding selection rules), these different "branch" transitions may or may not be observed. For our purposes, we will need to consider further only the "P" transition. In each of the systems to be described in some detail, all the frequencies observed in emission are attributable to P transitions (with identified values for V and J).

The nature of the energy input (or "pumping") truly distinguishes a "chemical" laser. Whereas commonly the energy source is provided by an external intense flashlamp, the source in the chemical laser is an exothermic chemical reaction. The product of a chemical reaction is a molecule bearing the reaction energy in the form of vibrational excitation. A "population inversion" is produced directly with the birth of the product. Subsequent emission in the infrared by the excited product is the source of the laser light. In the summary equations below, vibrational excitation is identified with the sumbol, †.

$$A + B \rightarrow AB^{\dagger} \qquad \text{(vibrationally excited)}$$

$$AB^{\dagger} \rightarrow AB + h\nu$$

The basis, then, of the chemical laser is "chemical activation."

For several years, the possibility of a chemical laser was the subject of widespread speculation and search. Finally in 1964 a type of "chemical" laser was reported by Professor Pimentel, based on research by his student, Jerome V. V. Kasper. A more apt term, however, is photodissociation laser; laser action was based on the photolysis of methyl iodide. The emitting species was an electronically excited iodine atom, indicated with the asterisk.

$$CF_3I \xrightarrow{h\nu} I^* + CF_3$$

The subsequent emission is by electronic transition specifically identified as $^2P_{1/2} \rightarrow {}^2P_{3/2}$. Here the symbol P is the electronic quantum number for orbital angular momentum. The superscript represents electron spin multiplicity. The subscript represents the coupling between spin angular momentum and orbital angular momentum. The transition yields a more weakly coupled state. The symbol P is coincidentally used here. It is not related to transitions in vibrational energy which were discussed earlier.

The term chemical laser (without the quotation marks) is applicable to another soon-discovered system (also by Kasper in Pimentel's laboratory). This was called the "explosion laser"; the first example reported was based on the reaction of atomic hydrogen and molecular chlorine. A manuscript (1) describing the discovery was soon dispatched. A copy was simultaneously provided for the information of AFOSR. The cover letter (21 January 1965) addressed to Dr. A. G. Horney is quoted below. It should impart some of the significance then assigned to the discovery.

> "Enclosed please find a manuscript entitled 'HCl Chemical Laser' that Jerry Kasper and I have just mailed off to *Physical Review Letters.* I know it will interest you–it is the outcome of Jerry's studies of the emission from the $H_2 - Cl_2$ explosion. As far as we know, it is another prototype laser, the first real chemical laser in the sense that excitation occurs through a chemical reaction: $H + Cl_2 \rightarrow HCl + Cl$. The CF_3I laser involved chemical bond rupture, but not a reaction of two or more chemical species."

Research in the field has been vigorously pursued in Professor Pimentel's laboratory (under continuing AFOSR support) and elsewhere. Five distinct types of chemical lasers have been reported so far by Pimentel (based, at last count, on 36 different chemical reactions). These types (and dates of discovery) are listed as photodissociation (1964); explosion, or three body, (1964); abstraction (1967); elimination (1968); and photoelimination (1969). We can see better just what these various types are with the aid of table 1.

It is not appropriate here to expand on the chemistry fundamental to operation of all the laser systems outlined in the table. In two instances, however, this will be attempted to some detail in order to reveal how laser performance does provide new insight to basic processes in chemical kinetics. The duration and intensity of output pulses are attributed to specific molecules and specific states of vibrational excitation. By adjustments in pressure, temperature, and composition, variations in laser performance are relatable to the causative kinetic processes. In Professor Pimentel's words: "A chemical laser under control is a poor man's molecular beam." Further exploration of the examples should reveal just what is meant by these words.

Explosion Laser

The operation of this system (2), which was the first encountered, is summarized by the following sequence (for H_2/Cl_2).

Flash initiation	$Cl_2 + h\nu \longrightarrow 2\,Cl$
(a)	$Cl + H_2 \xrightarrow{k_a} HCl + H$
(b)	$H + Cl_2 \xrightarrow{k_b} HCl^\dagger + Cl$

The final step provides the vibrationally activated species, $HCl^\dagger$, whose subsequent radiative relaxation is the source for lasing. The sequence of steps given is adequate to understand demonstrated effects of initiating flash energy, power, Cl_2 pressure, H_2/Cl_2 ratio, and total pressure.

Table 1. TYPES OF CHEMICAL LASERS

Type (Emitter)	Example
Photodissociation (1^*)	$CF_3I \longrightarrow I^* (^2P_{1/2}) + CF_3$
Explosion ($HCl^\dagger$, $DCl^\dagger$)	$H + Cl_2 \longrightarrow HCL^\dagger + Cl$
Abstraction ($HF^\dagger$, $DF^\dagger$)	$F + H_2 \longrightarrow HF^\dagger + H$ or $F + HR \longrightarrow HF^\dagger + R$
Elimination ($HF^\dagger$)	$CF_3 + CH_3 \longrightarrow CF_3\,CH_3^\dagger \longrightarrow HF^\dagger + CH_2\,CF_2$
Photoelimination ($HF^\dagger$, $HCl^\dagger$)	$CH_2\,CHF \longrightarrow CH_2\,CHF^\dagger$ $CH_2\,CHF^\dagger \longrightarrow HF^\dagger + CH\,CH$

Similar analysis was made of the isotopically substituted system: Cl_2, HD. Kinetic information never before measurable, with considerable impact on theory, is provided.

The chemistry basic to laser operation is described on two simultaneous chain sequences. As before, step (a) is rate determining [slower than step (b)].

$$\text{Iniation} \quad Cl_2 + h\nu \longrightarrow 2Cl$$

$$\text{(a)} \quad Cl + HD \xrightarrow{k_{aH}} HCL + d$$

$$Cl + HD \xrightarrow{k_{aD}} Dcl + H$$

Separate rate constants are indicated for formations of D and H, respectively. The constant k_{aH} governs formation of unexcited HCl (vibrational ground state) and, in the next rapid step, excited $DCl^{\dagger}$. Similar considerations hold for k_{aD}.

$$\text{(b)} \quad D + Cl_2 \longrightarrow DCl^{\dagger} + Cl \qquad \text{or}$$

$$H + Cl_2 \longrightarrow HCl^{\dagger} + Cl$$

The two rate constants, k_{aH} and k_{aD}, cannot be distinguished by classical methods (stiochiometry of products) because of the final step in the chain reaction. Each unexcited HCl is paired with a deuterium atom which subsequently provides an excited DCl. Similarly, formation of DCl assures formation next of excited HCl. This composite result is best revealed by adding steps (a) and (b). The product of HD + Cl_2 in one sequence is HCl + $DCl^{\dagger}$; in the others, $HCl^{\dagger}$ + DCl. Vibrational excitation is the real label which can, in fact, be identified from laser performance at associated, identified frequencies.

Observed in laser performance were two sets of operating conditions (same temperature and Cl_2 pressure, but varied H_2, D_2, and HD pressures) at which $HCl^{\dagger}$ and $DCl^{\dagger}$ emissions occurred with equal intensities. The ratios of HCl and DCl population inversions must have been the same for each set of conditions. The separate concentrations are relatable to the pressures of H_2 HD, and D_2 and the rate constants of the slow, rate determining steps in their formation k_a. The latter is known for H_2 and D_2. The pressures are also known for two sets of pressures yielding equal laser gains. The ratio k_{aH}/k_{aD} is thus calculated to be 1.9 ± 0.4. This determination assumes particular significance since it disagrees with existing theory which predicts a value 0.4 - 0.7.

Abstraction Laser

We shall consider in some detail the system UF_6/H_2^3.

Flash initiation $\quad UF_6 + h\nu \longrightarrow UF_5 + F$

$$F + H_2 \xrightarrow{k} H + HF^{\dagger}$$

The basic reaction of the abstration laser can lead to products at various levels of vibrational/rotational excitation (identified by vibrational quantum number V for HF). This is given in figure 2 in terms of the associated potential energy barrier for reaction, E_A, and appropriate forward and reverse rate constants, k and k′.

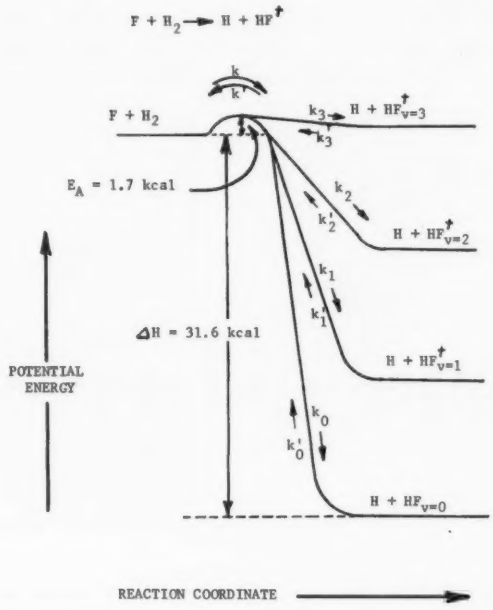

Figure 2.

By determining conditions whereby equal gain (intensity) and equal time delay before emission are displayed for two frequencies, relative densities of two associated energy levels N_v/N_{v-1} are calculable with available theory. It can be shown also that conditions are appropriate for a complete equilibration of rotational energy, but no deactivation occurs of vibrational energy by collision. It follows that the population ratio also equals the corresponding rate constant ratio, k_v/k_{v-1}. Specifically with F/H_2, for example, $k_2/k_1 = 1.38 \pm 0.10$.

Based on the Principle of Microscopic Reversibility, considerable significance is found for the deviation of the rate ratios from unity. A unit value is predicted by many theories of kinetics which presume vibrational degrees of freedom to be equilibrated with all other degrees of freedom in the activated complex (transition state for reaction appropriate to the peak of the potential barrier). The results for HF portend a severe impact on theory. They indicate that vibrational energy is more effective than translational in bringing about this particular endothermic reaction ($H + HF \longrightarrow F + H_2$).

In the example cited, the rate of formation was highest for products of the highest vibrational state, $k_v/k_{v-1} > 1$. This is not a general result, however. In some reactions, the ratio has been found to be less than unity. This fact has considerable implications that will guide emerging theory and understanding of reactive molecular collisions.

Understanding of the basic kinetic processes assists discovery, optimization, and interpretation of chemical lasers. Diverse Air Force applications in communication, reconnaissance, and other areas await new laser systems of varied output frequencies, higher operating efficiencies, increased power, and increased power-to-weight ratios. Some of these new systems will be "chemical lasers."

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Space Environment Forecasting System

Space Physics Laboratory, AFCRL

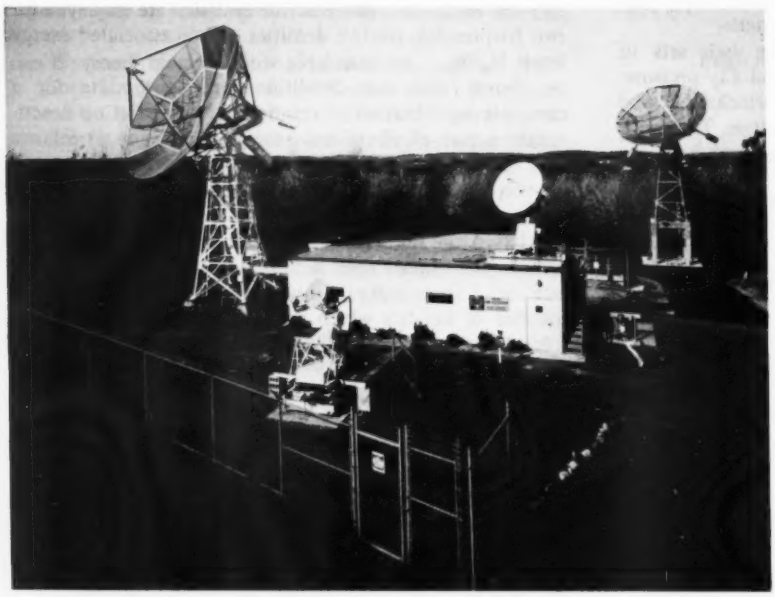

Figure 1. The radio observatory of North Ipswich, Mass., is operated jointly by AFCRL and the Air Weather Service. Here radio energy from the sun is monitored at a number of frequencies. These data are transmitted several times daily to the AWS computers at Offutt AFB, Oklahoma.

In June 1970, the basic components of a space environment forecasting system were placed in operation; this event marked a prominent milestone in the evolution of a major new Air Force system.

More than 50 ground-based stations (optical and radio observatories, and riometer, ionosonde, neutron monitor, and magnetometer sites) all over the world transmit teletype data as direct inputs to a system of four Univac-1108 computers at the Air Force Global Weather Central (AFGWC) at Offutt AFB in Omaha. Satellite data provide a direct input to the system. Data consist of solar activity, solar emissions, and solar-induced geomagnetic and ionospheric changes in the earth's environment. The computer system processes these data as a basis for forecasting changes in the earth's environment that affect Air Force communications, navigation, and surveillance systems.

Space environment forecasting started in 1962 when the Air Weather Service (AWS) was made responsible for observing and predicting conditions in the space environment that affect Air Force operations. In 1964, AFCRL was asked to assist. The system that was placed in operation in June is the product of a cooperative AWS-AFCRL undertaking.

The question that faced AFCRL in 1964 was simple enough, although the answers are still not fully defined. The question was "What observable features on the sun are likely to produce a given terrestrial effect?" The approach used was to accumulate a large base of data and to evaluate these data statistically for correlations.

Solar-geographical data extending back to 1955 were initially examined. This was the first time that large quantities of interrelated space environment data were assembled, error-checked, collated, and prepared for statistical analysis. The data base includes solar flares, sunspots, plages, 9.1 cm radio brightness temperatures, 10.7 cm solar radio flux, geomagnetic indices, and short-wave radio fadeouts. The statistical task was a straightforward process of associating the parameters physically related to the same phenomena—flares with sunspot groups, short-wave fadeouts with flares, and so on.

Such data, gathered for many years by scientists all over the world, were readily available. But soon after AFCRL began its study, it became clear that not much of the existing data was suitable. Errors, inconsistencies, different reporting standards, and instrument calibration variations invalidated much of the data in the reference literature. Scientists working with these data concluded that little reliance could be placed on historical data from general sources.

As a result, AWS and AFCRL had to embark on a parallel program to establish uniform observing and reporting procedures, and to design new and carefully calibrated observing equipment that would provide standardized information. The solar-geophysical data base for the system that was placed in operation in June is therefore the most consistent and error-free ever generated. Computer programs for accepting the incoming data, for processing them, and for forecasting various parameters were developed by AFCRL for the computer system.

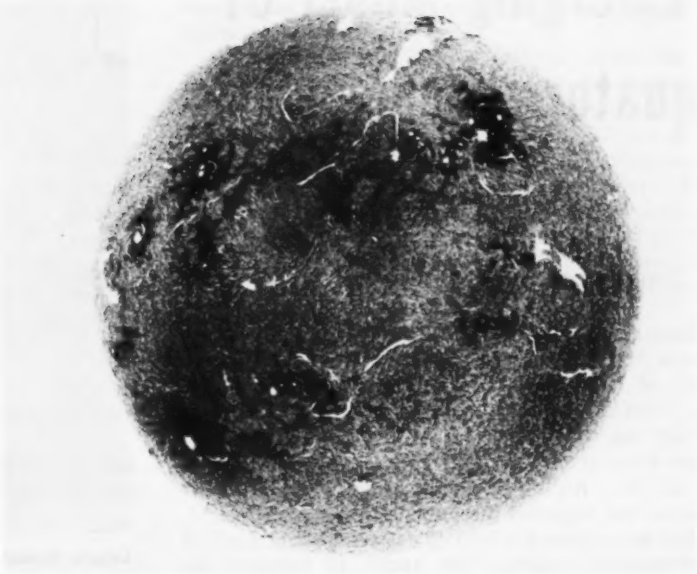

Figure 2. The face of the sun presents dynamically varying patterns—patterns which, it is hoped, can be associated with variations in solar emissions. This photo, taken in Ha light of an active sun, shows many of the sunspots, flares, and plages that are monitored by participants in the space forecast program.

As experience is gained in the operation of the new system, the predictions of solar-terrestrial effects should be made with more accuracy and for longer periods in advance. While the system supports the Air Force requirement for predicting anticipated degradations in the performance of Air Force electronic systems, it may prove also of great scientific value in accelerating our knowledge of how a specific solar variation translates itself into a specific set of terrestrial effects.

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Emerging Model Of Equatorial Ionospheric Scintillations

Ionospheric Physics Laboratory, AFCRL

During the flight of Apollo 11, communications between NASA's Apollo communications ships in the Pacific and the spacecraft were severely degraded during the night. NASA suspected that the explanation of this difficulty might be the ionospheric conditions near the equator where the Apollo ships were located. Consultation with AFCRL's Radio Astronomy Branch confirmed their suspicions and suggested that, during the Apollo 12 flight, the ships be positioned at least 15 degrees north or south of the geomagnetic equator. The Apollo 12 followed this suggestion and encountered no communications problems.

It would seem that any competent communications engineer would have initially planned for this simple solution, thus avoiding the Apollo 11 problem. But only within the past year has knowledge of ionospheric fluctuations–scintillations–in equatorial regions been refined sufficiently for such operational planning.

In several papers recently prepared by AFCRL radio astronomers, simple new models are presented of ionospheric scintillations on a global basis. These models take into account such parameters as sunspot number, magnetic index, latitude, season, and time-of-day. Although many sources provided the data used as the basis for these models, because AFCRL is the leading international center for ionospheric scintillation research, much of the data were accumulated by AFCRL observers.

Satellites have been indispensable in these studies. The researcher is interested in what effect the continuously changing ionosphere has on the signal passing through his ground receiver. Specifically, he is interested in the electron irregularities of the ionospheric F-layer. Patchy irregularities in electron concentrations, when transported by upper air winds, cause the rapid fluctuations in the signal known as scintillations.

VHF signals from many satellites have been used in AFCRL studies, with the best data obtained from the LES-5 (228 MHz), the Canary Bird (136 MHz), the ATS-3 (136 MHz) and the LES-6 (254 MHz). Most studies of signal fading and scintillations have concentrated on the Arctic regions which are still the primary focus of AFCRL's program. In these magnetically complex regions surrounding the geomagnetic pole, scintillations are pronounced and are of special interest from the standpoint of Air Force surveillance and communications operations located there.

Largely through the efforts of Dr. Jules Aarons, the AFCRL radio observatory in Hamilton, Mass., was established in 1958. Work at this observatory has focused on ionospheric scintillations and their effects on radio signals. Dr. Aarons is one of the international authorities in this field which is of great importance in the operation of navigation, communications, and surveillance systems.

More recently, increasing attention has been given to equatorial zone scintillations. Ionospheric irregularities, giving rise to scintillations along the geomagnetic equator during the night from about 2100 hours to 0400 hours, are as severe as those found in the Arctic. However, midlatitude regions are relatively free of signal-degrading scintillations.

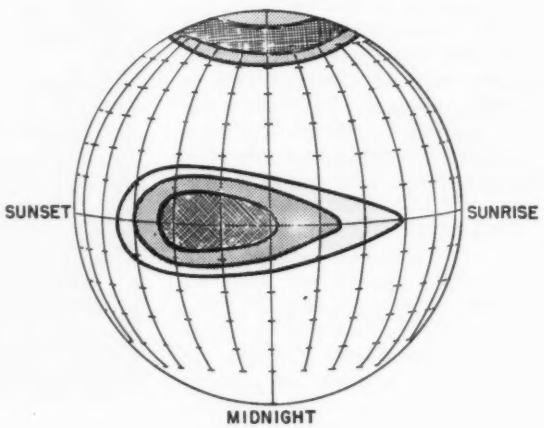

Figure 1. The irregular structure of the ionosphere at night. The radio astronomy group at AFCRL was the first to observe that scintillations occurring along the geomagnetic equator at night are as severe as those that have been observed in Arctic regions.

Following is a description of a typical record of equatorial scintillations: They start abruptly about three hours after sunset, frequently reaching maximum effects in a few minutes. The scintillations extend about 10° to 15° north and south of the geomagnetic equator. Once started, the scintillations maintain the level for several hours. However, their behavior may be different from night to night.

The nighttime irregularities are found to be in the F-layer at a mean height of 306 km. The irregularities themselves are elongated, cigar-shaped, electron patches, extending only about 225 meters in the east-west direction, but some 60 times longer in the north-south direction. These irregularities are moved by ionospheric winds across the propagation path of the satellite signal. By spaced-receiver methods, the velocity can be measured as a function of time. The F-layer drift is eastwards at night with velocities as high as 140 meters a second. The drift reverses direction at about 0600 in the morning and again at about 1930 in the evening.

A clear seasonal dependence has been observed, with maximum scintillations occurring during September and March, and minimum during December and June. Curiously, while solar activity (high sunspot number) tends to increase the scintillation index, it decreases the latitudinal extent of the scintillation region.

A model, developed by AFCRL to explain the equatorial irregularities, begins with the fact that the height of the ionosphere F_2 layer decreases markedly during the night—from as much as 600 km at 2100 to 275 km at 0400. With this fact, let us consider two vertical profiles, one east of the other. When the height begins to fall after 2100, the eastward point will have both a lower electron density and lower height than the westward station which is functioning at an earlier local time. The moving east-west gradients in electron density profiles, according to the model, generate waves producing the irregularities.

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SOLAR ULTRAVIOLET VARIATIONS OVER A 27-DAY PERIOD

Aeronomy Laboratory, AFCRL

A paper, "Solar Radiation in the Extreme UV and Its Variation With Solar Rotation," recently submitted to the *Journal of Geophysical Research* by Drs. L. A. Hall and H. E. Hinteregger of AFCRL, reviews the data from an AFCRL grazing incidence grating spectrometer operating in the 1310 to 270 angstroms range and carried aboard NASA's OSO-III satellite. The primary conclusion in the paper was that the variations occurring during the 27-day rotation period are similar to those observed over the 11-year solar cycle when wide variations would be expected. However, solar ultraviolet radiation can vary markedly—by as much as 40 percent—over the period of one solar revolution.

Largely because of shielding and damping by the atmosphere, variations in solar UV emissions tend to be smoothed out, and therefore they go unnoticed. Solar untraviolet radiation, nevertheless, modulates the earth's environment in profound ways—sustaining the continuous chain of chemical reactions in the earth's atmosphere, altering the character of the ionosphere, keeping the earth's climate in equilibrium, and providing essential energy for plant and animal life. Ultimately, but not soon, observed solar UV variations may be applied to the prediction of specific terrestrial effects. Such translations presently have eluding complexity.

The 27-day variations in solar ultraviolet radiation, discussed by Hall and Hinteregger, were not the product of large energetic flares, although such flares do bring sharp increases in solar UV emissions. The variations had no single cause, but emerged from the continuous shifting convections, the rolling energies, the innumerable minor flares and explosions in random patterns, and the small crescendos of solar activity. Such activities, at any given time, may be more pronounced on one side of the sun than on the other.

The OSO-III was launched on March 8, 1967. The AFCRL spectrometer aboard the satellite yielded the most detailed spectral coverage obtained to date on that part of the solar extreme UV that affects the atmosphere. Prior to that time, and for well over a decade, Dr. Hinteregger and his group at AFCRL had launched scores of UV detectors aboard Aerobee rockets from the White Sands Missile Range. But rocket observations have the obvious limitations of short ob-

servation time and atmospheric interference.

The OSO-III experiment was the first to give AFCRL researchers the opportunity of observing daily variations in solar UV emissions without the necessity of correcting for atmospheric effects. Moreover, the resolution of the spectrometer aboard the satellite gave a clear view of the changing spectral character of the UV emissions.

The spectral character of emissions is of particular interest. When speaking of increases or decreases in solar UV emissions, we are referring to the average of many emissions at discrete wavelengths from many ionized species. Hall and Hinteregger consider some 20 emission lines over the 1310 to 270 angstroms region of their instrument–for example, He I at 584.3 angstroms, N II at 1085, Mg X at 625.3, and Fe XVI at 335.5. These 20 ionized species do not increase or decrease their emissions in unison. Increases or decreases depend on their ionization potential; this potential depends on the thermal environment at some particular location on the sun. Hall and Hinteregger concentrate on data from one 10-day period, May 15 to May 24, 1967. Although the average ratio of solar EUV flux in that period was 1.4, the average ratio for such ions as Fe XVI was 2.9; whereas for N III it was 1.3, and for Si III it was 1.5.

During the 10-day period, ions with the highest ionization potentials produced the largest flux increases. However, during large energetic flares, the largest flux increases came from those ions in the middle range of ionization potential.

How do general increases in solar UV correlate with flux increases at much longer wavelengths–say, radio wavelengths at 10.7 cm? During the 27-day variation reported in the study, the 10.7 cm flux (measured by ground-based radio monitors) increased from 111 to 201. The relationship between the 10.7 cm and EUV increases is similar to that observed by AFCRL over an 11-year cycle. A 50 percent increase in solar UV flux during the 11-year cycle was accompanied by an increase of from 75 to 150 in 10.7 cm radio flux.

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Dr. L. A. Hall
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Dr. Hans E. Hinteregger's biography appeared on page 28 of the May/June 1970 issue of the OAR Research Review.

Dr. H. E. Hinteregger (left) and Dr. L. A. Hall study the data on solar ultraviolet emissions obtained from the OSO-III satellite during a 27-day period.

Dr. L. Alton Hall has been a research physicist (atomic and nuclear) in the Solar Ultraviolet Branch, Aeronomy Laboratory, at AFCRL since 1959. He is currently concerned with the measurement of extreme ultraviolet solar radiation in the upper atmosphere, utilizing rocket- and satellite-borne instruments.

Dr. Hall received a B.S. from Wake Forest College in 1950 and a Ph.D. from the Johns Hopkins University in 1956. He is a member of the American Physical Society and the American Geophysical Union, and has published frequent articles on the results of his research.

subtle english dialects

Data Sciences Laboratory, AFCRL

All writers have experienced this situation. A paper goes through the hands of an editor who makes a seemingly superficial change in the structure of a sentence. The writer may wonder why the editor made the change, but shrugs it off because the meaning does not seem to have been altered. Still, he prefers his original sentence.

What may by happening is that the writer and the editor are speaking different dialects–subtly different to be sure–but nevertheless different. Each feels more comfortable with his own construction. Captain Guy Carden of AFCRL deals with the matter of dialects in several recent papers. The subject is more than a simple investigation into human behavioral patterns. It has rather basic implications to the problem of machine translation of languages and to the programing of computers in natural languages.

A clear example of the sort of individual dialect variation that Carden has been studying involves negatives (words like "not" and "non-") and quantifiers (words like "all," "every,"

or "many"). Speakers may be divided into three dialects according to their interpretation of a sentence such as this: "All the bombs didn't hit the target." Some people associate the negative with the quantifier and interpret the sentence as meaning "Not all the bombs hit the target." Others associate the negative with the verb or predicate, and these negative-verb speakers interpret the sentence to mean "All of the bombs missed the target." The third dialect group concedes that the original sentence can have either interpretation. These three dialects do not seem to be related to region, education, or social class. Speakers of one dialect sometimes refuse to believe in the existence of the other dialects.

The problem for the linguist is to explain the relation between the surface form of the sentence—the actual words one writes or says—and its meaning. The different meanings of the sentence, "All the bombs didn't hit the target," arise because those in the three dialect categories use different rules of language. It is the job of the linguist to show how the grammars of the dialects differ.

To do this, linguists analyze sentences on two levels: (1) surface structure, corresponding roughly to a grammar-school parsing of the sentence; and (2) deep structure, representing the meaning. These levels are related by a series of rules which, in the ideal case, should be precise and explict enough for a computer to do the analysis. Starting from the relatively obvious surface structure and an intuitive feel for the meaning, the linguist attempts to find evidence determining the exact form of the deep structure and the rules relating this deep structure to the surface structure.

One approach used by the linguist is to alter the structure of the sentence in various ways to see what happens—a sort of theme with variations. Taking the original sentence, suppose we add the tag question, "All the bombs didn't hit the target, did they?" We discover that the speaker in the third dialect category who found the original sentence ambiguous now finds the meaning to be quite clear. It has only the negative-quantifier meaning, "Not all the bombs hit the target, did they?" But the negative-verb dialect speaker now runs into difficulty. He subconsciously rephrases the sentence to read, "All of the bombs missed the target, did they?" which is unacceptable grammatically. Notice that in both cases, it is the negative-verb meaning that is rejected.

By carrying this sort of analysis through a number of variations, it is possible to determine the correct deep structure for quantifiers—a matter that linguists have been debating for some years. Carden argues that the sort of dialect evidence that we have been discussing shows that quantifiers have a special status in English, rather like that of a special operator in formal logic. He suggests that human language in general has more in common with formal logic than linguists had previously thought.

For the non-linguist, the simple case examined above may serve to show some of the difficulties in man-machine communications. Certainly, such studies are prerequisite in man-machine interactions in which a computer must "understand" human language. If a computer were designed and programed to understand the negative-verb dialect (perhaps by a designer who didn't even know that other dialects existed), then there could be a communications gap between the computer and someone with a negative-quantifier dialect wishing to use it.

Capt. Guy Carden's work in computer languages is concerned with problems of machine translations and programing of computers in a natural language, rather than in artificial languages such as COBOL, FORTRAN, and LISP.

Contact: Captain Guy Carden
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Captain Emmet Guy Carden has been a research scientist in the Applied Mathematics Branch of the Data Sciences Laboratory, AFCRL, since 1967. At present, he is studying the interactions between syntax and semantics through the logical structure of natural language, and the possibility of using natural language in computer programing, in command and control systems, and in machine translation.

Captain Carden earned his A.B. (1966) in Linguistics and Mathematics, his A.M. (1967), and Ph.D. (1970) in Linguistics, all with honors at Harvard. He is a member of the Linguistic Society of America and has several publications to his credit.

flow studies with pulsed laser holography

George Havener, Capt., USAF
Hypersonic Research Laboratory, ARL

A transmission holographic optical system is being developed for fluid flow visualization in the Mach 3, high-Reynolds-number wind tunnel at ARL. The project is following a programed development wherein two-dimensional, well-documented laboratory test subjects are holographically analyzed before the system is applied to high-speed complex-flow studies. Thus far, the results are encouraging and demonstrate the utility of holography which has produced reliable shadowgraph, schlieren, and interferometric data from a relatively simple and inexpensive holographic optical system.

The basic optical arrangement is a folded, single pass, parallel beam schlieren system. To satisfy the requirements for holography, a reference path is established by separating a portion of the original beam with a beam splitter. The general configuration for making a holographic recording of an event and the essential components in the system are shown in figure 1. Two lasers are used in the system: one is a continuous wave laser used for both system alignment and reproduction of the scene from the processed hologram; the other is a pulse ruby laser used for the actual recording of the event. The requirements for holography and additional information on this specific system are found in references 4 and 1, respectively.

The scene beam in this system is a parallel beam that directly illuminates the event. The ground glass, commonly used to create a diffused background illumination in many transmission holographic systems, is omitted; consequently, the reconstructed image of the event is a real image which is easily projected from the hologram and analyzed, using conventional shadowgraph, schlieren, and interferometric techniques. The reconstruction of a sample event is schematically illustrated in figure 2.

Thus far, the results obtained from this system are two-dimensional—the scope of the current studies. To investigate the three-dimensional features of holography, the system shown in figure 1 would have to be changed because only two-dimensional views can be observed with a collimated scene beam.

Holographic interferometry appears to be an accurate method for mapping the density fields of two-dimensional subjects. Several techniques are available for making holographic interferograms. To date, two methods have been examined in this project: in one method, the interference pattern is recorded on a single hologram; in the other method, the interference is created during the reconstruction of the event from two separate holograms.

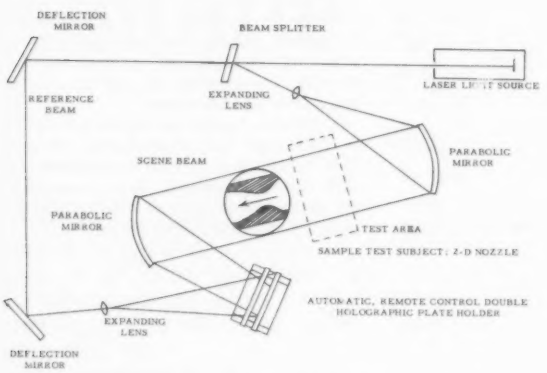


Figure 1. Schematic representation of the system used to holographically record the event.

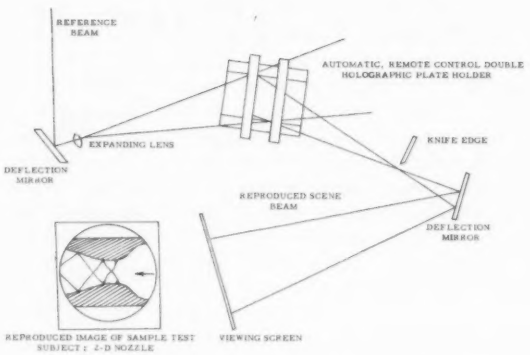


Figure 2. Schematic representation of the system used to holographically reproduce the event.

In holographic interferometry, the identification of an interference pattern associated solely with the specific behavior of an event requires two separate exposures of the test subject. The first exposure contains information on the undisturbed test; the second exposure provides data on the disturbed test (actual experiment). In the single hologram method, both exposures are recorded on the same hologram. In the double hologram method, the undisturbed and disturbed exposures are recorded on separate holograms.

In the single hologram method, if the hologram moves between exposures, the optical reference changes and fringes appear that are not associated with the behavior of the event. If the movement is very slight, on the order of a few wavelengths, the additional fringes appear as uniformly-spaced parallel lines in regions not affected by the actual behavior of the test; these additional fringes establish a new reference that is typically related to the ambient conditions, and the resulting fringe pattern is analyzed as a finite fringe interferogram. There are two extremes in this method: absolute stability, or gross movement, during the recording of a test. With absolute stability, the interferogram shows a fringe scheme comparable to an infinite fringe pattern wherein the fringes represent lines of constant density. This type of interferogram is convenient and easy to analyze because knowing the value of the density on a specific fringe automatically describes the entire density field explicitly defined by the fringes. Where gross movement has occurred, the optical reference is sufficiently disturbed to destroy the interference; hence, no discernable pattern is observed and the test must be repeated.

To date, the interferograms obtained from the single hologram method closely approximate infinite fringe interferograms. There are, however, stray fringes in the reference positions which suggests that a change in the optical reference occurred between the two exposures. This change may have been caused by a small movement, or by a slight change in the environmental conditions, or by small optical phase differences between the two separate laser pulses. Therefore, the ideal infinite fringe interferogram is difficult to obtain; but, under certain conditions, the stray fringes that appear in the reference position can be ignored, and the fringe pattern can be analyzed with sufficient accuracy as an infinite fringe interferogram.

In the double hologram method, the undisturbed and disturbed scenes are recorded on separate holograms, and an interference pattern is observed only during the simultaneous reconstruction of each scene. The separate scenes are superimposed during the reconstruction step, and the formation of a specific fringe pattern is controlled by the relative spacing (realignment) between the holograms. Because this realignment is critical, sensible interference patterns result only when the original spacing and alignment of the holograms are reproduced to within several wavelengths of accuracy. Since accurate alignment requires micrometer type controls conventionally associated with Mach-Zehnder interferometry, a device which has six degrees of fine control for each hologram is being designed; it will be used to record and reproduce both the undisturbed and disturbed scenes. Further investigation of this method of holographic interferometry is being postponed until the required double hologram holder is constructed.

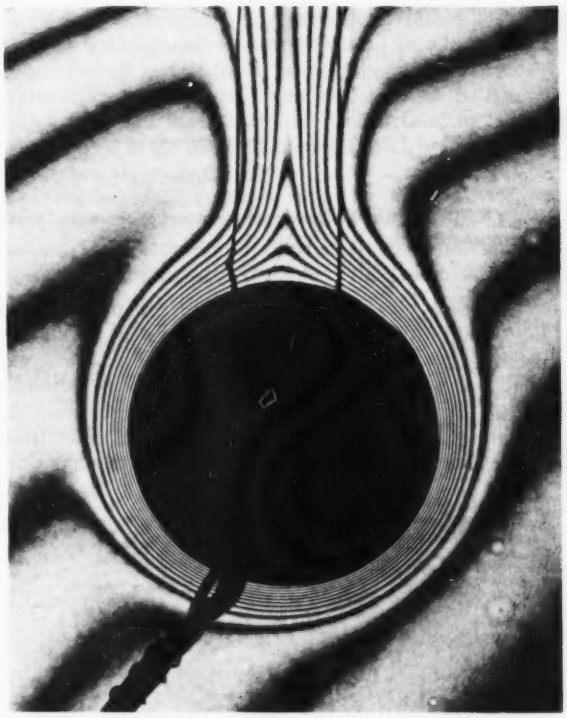


Figure 3. Holographic interferogram of a uniformly heated horizontal right-circular cylinder.

Figure 3 is a holographic interferogram of free heat convection from a horizontal cylinder. The interferogram appears to be a typical finite fringe interferogram because the reference position, regions outside the temperature boundary layer, contains several fringes. The fringes in the temperature boundary layer, however, resemble fringes that are similar to a typical infinite fringe arrangement. Since the temperature change in the boundary layer is the dominant factor causing the fringes to appear, the stray fringes in the reference position were assumed to have a small effect on the fringe configuration in the boundary layer. Hence, the fringes in the boundary layer were assumed to be lines of constant density, and the fringe pattern was analyzed as an infinite fringe interferogram. The validity of this assumption was established by comparing the wall temperature calculated from the interferogram data with the wall temperature measured with thermocouples. Since the two values of wall temperature differed by less than 1 percent, the infinite fringe assumption was considered realistic for this test.

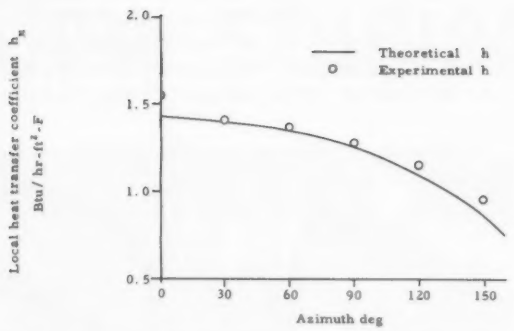


Figure 4. Comparison between theoretical and experimental heat transfer coefficients.

Further data were obtained from the interferogram: local temperature gradients dT/dx, determined from temperature distributions at different cylinder locations, were used to calculate local values of h, the heat transfer coefficient. Figure 4 shows a comparison between the experimentally calculated values and the theoretically predictable values. The largest deviation between the two values occurred at the lower stagnation point on the bottom surface of the cylinder wall. Close examination of the interferogram, figure 3, reveals that the fringes appear to merge with the lower wall, indicating that the cylinder was slightly misaligned. This small misalignment affected the value of the calculated temperature gradient and caused the error in the experimental value of h. Along the sides of the cylinder, however, where the misalignment did not significantly affect the calculation of dT/dx, the experimental and theoretical values of h agreed very well.

Figure 5 shows another heat transfer test subject analyzed, using holographic interferometry. The study was of free heat convection from a vertical flat plate. The specific purpose of this subject was to compare experimental and theoretical temperature distributions in the boundary layer. In the analysis of the interferogram, the fringe pattern was assumed to be of an infinite fringe arrangement. The previous remarks about the horizontal cylinder are also applicable for this test. The validity of the infinite fringe assumption was established by comparing the measured and calculated wall temperatures; again, the difference between the two values of wall temperature was less than 1 percent.

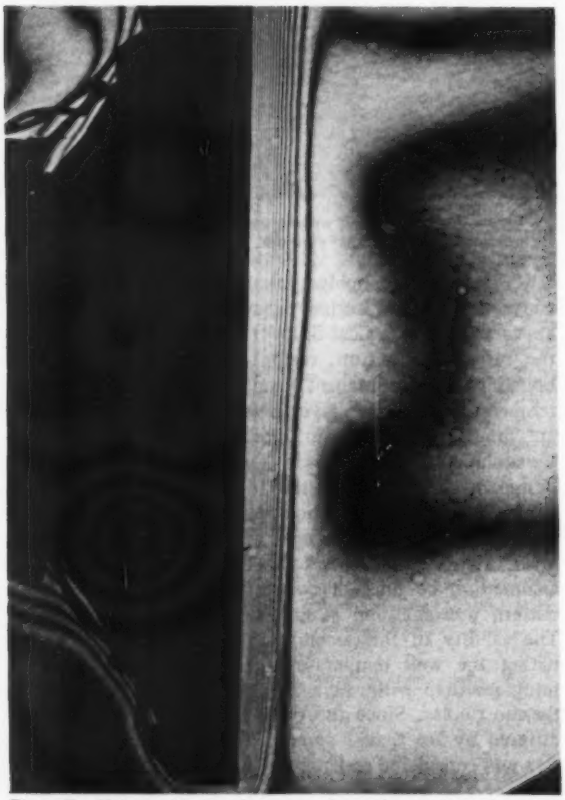


Figure 5. Holographic interferogram of a uniformly heated vertical flat plate.

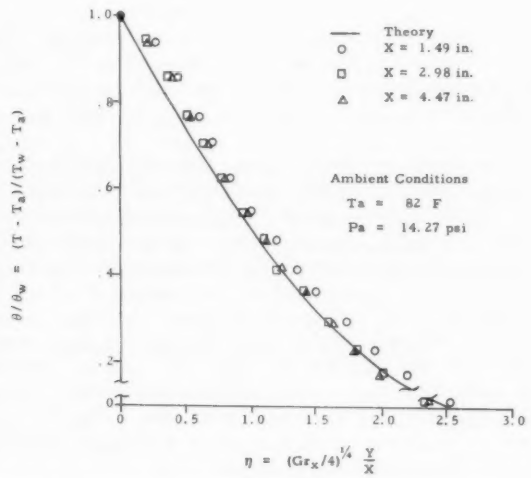
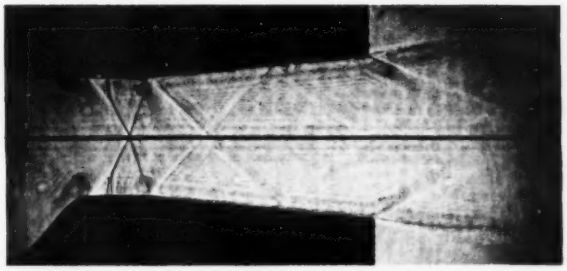
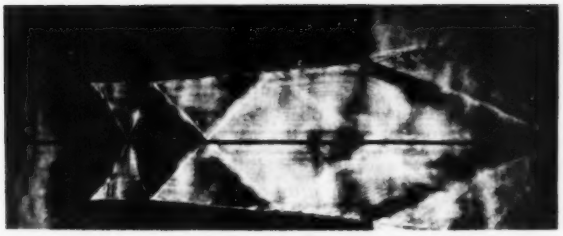


Figure 6. Comparison between theoretical and experimental dimensionless temperature distributions for free convection heat transfer from a vertical flat plate.

The theoretical temperature distribution through the boundary layer at any point along the plate wall is defined by the solid line in figure 6, and three locations where the temperature distribution was experimentally determined from the interferogram are shown as data points. To be consistent with the theoretical results found in (2), the temperature profiles are presented in nondimensional form. The results of this test are very satisfactory because the average difference between the experimental and theoretical temperature distributions is about 5 percent.



SHADOWGRAPH



SCHLIEREN

Figure 7. Shadowgraph and schlieren photograph made from one hologram of air flow in a 2-dimentional supersonic nozzle; M = 1.75.

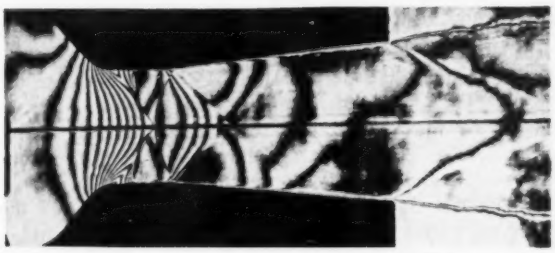


Figure 8. Holograph interferogram of air flow in a 2-dimensional supersonic nozzle; M = 1.75.

Figures 7 and 8 show the holographic results of air flow in a two-dimensional supersonic nozzle. The shadowgraph and schlieren pictures were made from the same hologram, but the interferogram in figure 8 was made from a separate hologram that had been double exposed. The interferogram was used to calculate the local centerline density in the exit plane of the nozzle, and the shadowgraph and schlieren pictures were used to qualitatively depict the flow field.

While the strong features of the flow are readily observable in figure 7, the turbulence in the nozzle is not very well defined. It is believed that the resolution of the turbulence was diminished during the reconstruction of the event because the original relationship between the reference beam and the hologram was not sufficiently reproduced. Since the rays in the reference beam diverge in both the formation and the reconstruction of the hologram, it is nearly impossible to reproduce the correct incident angle at which each ray strikes the hologram. The resolution of the turbulence is believed to be sensitive to small inaccuracies in the reconstruction step; therefore, future tests will employ a collimated reference beam to permit, hopefully, more correct and accurate reconstruction of the event. In spite of the loss of detail in the turbulence of the flow, the Mach lines and shock waves are well defined in figure 7, particularly in the schlieren photograph where the direction of the density gradient is visible.

The studies performed thus far have provided encouraging results because meaningful data have been obtained from a conventional schlieren configuration modified for transmission holography. While the basic development of the system is nearly complete, the investigation of applications and techniques has a long way to go. Future studies will investigate the double hologram techniques for making interferograms, examine the effects of using a collimated reference beam, and investigate some of the attractive (but not well understood) features of three-dimensional holograph measurements.

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Captain Albert George Havener has been with the Hypersonic Research Laboratory of ARL since March 1969. He received the B.S. degree in Mechanical Engineering from the University of Wyoming in 1967 and the M.S. degree in Aerospace Engineering from AFIT-SE in March 1969. His early years in the Air Force were spent as a weather observer at various Air Force bases (1959-1964).

Rugged, Inexpensive Schlieren System

Space Physics Laboratory, AFCRL

Figure 1. Dr. Joseph G. Kelley (left) and Robert A. Hargreaves demonstrate the operation of their simplified schlieren system.

Mr. Robert A. Hargreaves is an electronic development technician in the Space Physics Laboratory at AFCRL. He is currently working on the development, maintenance, and operation of electrical and electro-optical devices for investigating plasma heating and containment.

Before joining AFCRL, Mr. Hargreaves worked for private industry and served his military tour of duty with the Army Air Corps.

Dr. Joseph G. Kelley is a research physicist in the Energetic Particles Branch of the Space Physics Laboratory at AFCRL. Using appropriate computer techniques, he now analyzes and evaluates data on the Van Allen belts, data gathered by the OV1-13 satellite. He relates these data to existing physical theories, develops new theories, and plans future satellite experiments on the radiation environment of near-earth space.

Dr. Kelley received a B.S. from Trinity College in 1956 and an M.S. (1958) and Ph.D. (1960) in Physics from Yale University. He has published a number of scientific articles and is a member of Phi Beta Kappa, Sigma Xi, Sigma Pi Sigma, the National Honor Society, and the American Physical Society.

Schlieren photography makes it possible to see that which otherwise would not be apparent–such as the flow of air around objects. We have all seen schlieren pictures; usually they show the pattern of turbulences and laminar flow around bullets or model nose cones.

Such photography is possible whenever the subject to be photographed has strong refractive index gradients. Dr. Joseph G. Kelley and Robert A. Hargreaves of AFCRL, in the April 1970 issue of *Applied Optics*, report on "A Rugged Inexpensive Shearing Interferometer" system that produces schlieren-like photos of excellent resolution. Their apparatus is enclosed in a box measuring 3 feet by 9 feet; but the system can be scaled up or down, depending on the needed size of the test region.

The setup, which is quite simple, requires no critical adjustments. A parallel beam of coherent light is provided by a 1 millwatt helium-neon laser. An exposure control shutter is placed in front of the beam. The shutter is followed by a divergent lens with a focal length of a few centimeters. The laser light, spread by the divergent lens, impinges on a 6-inch parabolic mirror. The parabolic mirror then directs the laser beam (now parallel again after being broadened by the divergent lens) through the test region to the test mirror that is set at about 45° with respect to the beam. This mirror, an ordinary back surface mirror, is critical to the system. Two overlapping, slightly offset images are reflected from the mirror: one from the front glass surface and one from the silvered back surface.

The test object is placed in the region between the parabolic mirror and the test mirror. Any refractive index gradients perpendicular to the laser beam occurring in the test region environment will delay (alter the phases of) rays passing through the test region. The slight delays in propagation create fringes in the overlapping images reflected from the test mirror. These fringes correspond to refractive index gradients which, in turn, delineate the pattern of turbulence or air flow. The fringes may be observed directly or recorded on a sheet of film.

Both still and motion pictures of laminar flow and turbulence around objects have been made by Kelley and Hargreaves. The pictures match the quality produced by more elaborate and expensive systems.

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temperature, winds, and sst fuel consumption

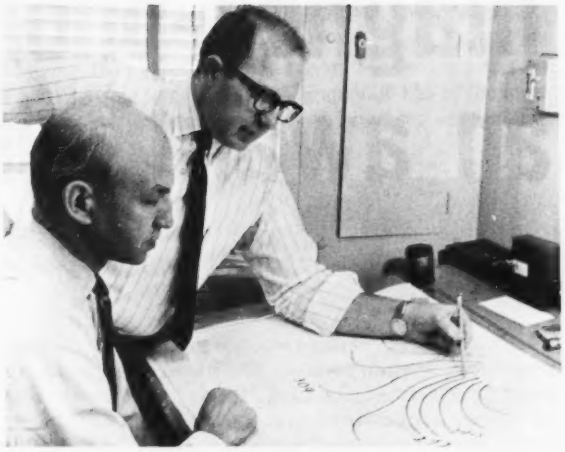
Aerospace Instrumentation Laboratory, AFCRL

A 1969 study (Crossley) produced some interesting figures on supersonic aircraft fuel consumption as a function of temperature and headwind. For example, an increase of just 1°C over the mean route temperature will cause an SST flying between London and New York to use 400 to 600 pounds of additional fuel. For each knot above the mean headwind, an SST flying at roughly 20 km altitude over the same route will use an additional 100 pounds of fuel. While these figures will vary with engine and aircraft design, the variations are slight. Both the commercial SST and operational military aircraft will be using polar (stratosphere) routes where extreme variability in temperatures and winds takes place.

Donald Grantham, Arthur J. Kantor, and co-workers of the Design Climatology Branch of AFCRL have recently considered polar winds and thermodynamic properties of the atmosphere above 20 km in connection with a pending revision of DOD MIL-STD 210A, Climatic Extremes for Military Equipment. In this document, standards for the design and operation of military equipment are referenced. In military aircraft operations where fuel reserves are sometimes minimal, the probabilities of extremes in temperatures and winds must be known precisely by the planners of operational missions.

Atmospheric scientists are especially concerned with a feature of polar meteorology known as "explosive warmings." These warmings, which seem to precede the breakdown of the strong polar cyclone in winter, sometimes increase temperatures at SST cruising altitudes by more than 20°C in a 24-hour period.

With respect to stratospheric polar winds, Grantham and Kantor have concluded that the severity of these winds may not be as great as previously reported. Stratospheric winds of 200 to 300 knots have been measured by Canadian meteorologists and were also not uncommon in reports of measurements made before 1966. Since that time, there have been few reports of winds of this magnitude. Grantham and Kantor suggest that the measuring instrumentation and procedures used before 1966 probably caused exaggerated figures. In any event, they consider the extraordinarily strong polar wind measurements at altitudes above 20 km made before 1966 to be unreliable. Such data should not be used in climatologies related to the design and operation of supersonic aircraft in the Arctic stratosphere.



Arthur J. Kantor (left) and Donald Grantham study wind gradients in the northern latitudes.

Since October 1960, Mr. Arthur J. Kantor has been a research meteorologist in the Design Climatology Branch of AFCRL's Aerospace Instrumentation Laboratory. He now manages research in meteorology and climatology, specializing in problems on the variability and interrelationships of atmospheric parameters and in theories on the structure of the upper atmosphere.

Mr. Kantor received a B.S. in 1950 from the Pennsylvania State University and has taken graduate courses at Rutgers University, Massachusetts Institute of Technology, and Framingham State College. He is a member of the American Meteorological Society, an honorary member of Phi Eta Sigma and Sigma Gamma Epsilon, and has published frequent articles in scientific media.

Mr. Donald D. Grantham has been a research meteorologist in the Design Climatology Branch of AFCRL's Aerospace Instrumentation Laboratory since 1963. He is presently developing mathematical, statistical, and graphical techniques to describe the variation in time and space of atmospheric parameters– parameters such as temperature, humidity, density, pressure, and winds–which affect missile design and operation.

In 1958, Mr. Grantham received his B.S. in Mathematics and Physical Science from the Ball State University in Indiana. While on leave of absence from AFCRL, he earned an M.S. in Meteorology at the University of Michigan in 1969. He is now a member of the American Meteorological Society and Sigma Zeta (National Science Society, Honorary) and has made many presentations at scientific conferences on the results of his work. His presentations were usually published in the conference proceedings or as AFCRL technical reports.

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magnon-phonon conversion an award winning paper

Microwave Physics Laboratory, AFCRL

From the 174 papers published in scientific journals in 1969 by AFCRL scientists, "Transmission-Line Models for Magnetoelastic Modes in Saturated Ferrimagnets," published in the April 1969 issue of *IEE Transactions on Sonics and Ultrasonics,* has been judged to be the most significant AFCRL paper. In recognition, the author, James C. Sethares, will receive AFCRL's Marcus D. O'Day Memorial Award.

The research reported in the paper brings closer to realization the promised new technologies of microwave acoustics. A range of new devices–harmonic generators, transducers, delay lines, detectors, and filters–based on the generation and manipulation of elastic waves in solids are emerging from microwave acoustics research. Much of this research is presently focused on more efficient methods for converting electromagnetic energy to acoustical energy and for reconverting acoustical energy to electromagnetic energy.

Sethares' paper deals with this problem. But, instead of coupling electromagnetic energy directly to an acoustic material by physically attached transducers or by piezoelectric materials placed in an electromagnetic resonant cavity, he exploits the magnetostrictive properties of saturated ferrimagnetic materials. By applying a magnetic field to any magnetostrictive material, the material itself becomes elastic and changes dimensions. Thus, at least superficially it would seem that direct coupling to such materials would provide an easy and efficient method for the generation of magnetoelastic waves. For many reasons, this procedure cannot be used directly.

Sethares demonstrates an indirect procedure. He describes several circuit models in which magnetic waves, generated in saturated ferrimagnetic materials, produce elastic waves in a solid. These circuit models were originated by considering the behavior of magnetoelastic waves at microwave frequencies. The behavior of these waves resembles that of electromagnetic waves along transmission lines; this resemblance suggested to Sethares that transmission-line analogs for magnetoelastic waves could be developed. He reasoned that if these analogs were developed, existing electrical transmission-line theory could be applied to the problem of magnetic and elastic wave coupling.

To apply existing transmission-line theory, it was necessary to translate a multitude of electrical transmission-line formulas into equivalent physical formulas. When this was accomplished, Sethares was able to deal with the problem in more familiar terms and to analyze the complicated relationships among the many parameters. The real significance of his research was not in the circuit models described in the paper, but in the translation of theoretical concepts into engineering terms that can be readily applied by all researchers in the field.

However, the circuit models that he derived from the equivalent physical formulas should not be disparaged. One transmission-line model consists of two parallel transmission lines which Sethares labels a magnon line and a phonon line, respectively. Magnetic waves generated in the magnon line are inductively coupled to the phonon line through a coupling network. This coupling action sets up elastic waves in the phonon line which are propagated in a specified direction.

James C. Sethares is shown reading his award-winning paper which translates certain theoretical concepts into more conventional engineering terms to simplify the design of microwave acoustic devices.

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The biography of Mr. James C. Sethares appears on page 3 of the January-February 1970 issue of the OAR Research Review.

State-of-the-Art Surveys On Microwave Acoustics, Terrain, & Solar Elevations

Microwave Physics, Terrestrial Sciences, and Optical Physics Laboratories, AFCRL

A basic part of the AFCRL mission is the preparation of state-of-the-art surveys in given research fields and the editing of handbooks for use by specialists in these fields. Following are reviews of three recently published AFCRL reports of special merit.

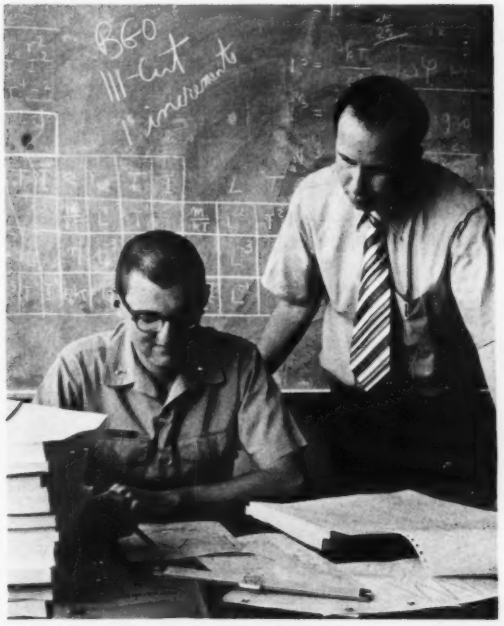
Microwave Acoustics Handbook

The 350-page volume, "Microwave Acoustics Handbook," (*AFCRL-70-0164*), was prepared by Lt. A. J. Slobodnik, Jr., of the Microwave Physics Laboratory, and E. D. Conway as the first volume of a projected series for use as a basic guide by all researchers in the expanding field of microwave acoustics.

Microwave acoustics is a rapidly expanding field of electronics research. Only within the past few years has its promise for device application come within reach as researchers have succeeded in exploiting the potential of surface wave phenomena. Such waves are elastic waves that propagate along the surface of certain solids. The functions of a host of electronic components can be carried out more efficiently and in much smaller packages by using acoustic techniques.

A current microwave acoustics research goal is to identify new solid materials in which a surface wave can be generated and propagated with minimum attenuation along the surface. Another goal is to find improved methods for coupling electromagnetic energy to the solid to produce acoustic energy.

In the "Microwave Acoustics Handbook," the acoustic wave properties of 22 of the known acoustic materials are examined–from $Ba_2NaNb_5O_{15}$ (which researchers have labeled "bananas") through $LiNbO_3$ (lithium niobate, currently the best performing acoustic material) to ZnO. The handbook consists largely of curves and tables of these 22 materials, giving surface wave velocity as a function of crystal lattice orientation and also the depth and character of the surface wave in the material. The handbook was prepared both to eliminate needless duplication among different research groups and to acquaint newcomers in the field with the current state of the art. It also contains a list of material constants and a bibliography of 135 of the more significant surface wave papers that have been published to date.



Lt. Andrew J. Slobodnik, Jr., and E. D. Conway review some of the figures included in the *Microwave Acoustics Handbook*.

First Lt. Andrew J. Slobodnik, Jr., is an electronics engineer in the Microwave Acoustics Branch of the Microwave Physics Laboratory at AFCRL. He is currently engaged in theoretical and experimental investigations of microwave acoustic wave propagation with both standard bulk-type waves and surface elastic waves.

In 1966, Lt. Slobodnik received his B.S. and M.S. degrees in Electrical Engineering from the Massachusetts Institute of Technology. While attending MIT, he worked as a cooperative student at AFCRL.

Lt. Slobodnik received the Marcus D. O'Day Memorial Award for the best AFCRL paper published in a recognized scientific journal in 1967. The paper, "Microwave Rectification Using Piezoelectric Quartz and Zinc Oxide," J. Appl. Phys., Vol. 38 (Dec. 1967), 5153, was co-authored with Paul H. Carr. Lt. Slobodnik has published several other articles on his work and made a number of presentations at symposia.

Mr. Edward D. Conway is a senior mathematical analyst with Analysis and Computer Systems, Inc., where he has been employed since 1968. He is currently performing research, under contract, for the Microwave Physics Laboratory of AFCRL.

Mr. Conway received his B.A. in Mathematics from Boston College (1966) and his M.A. in Mathematics from Boston University (1968), where he is now studying for his doctorate. Mr. Conway is a member of the Association for Computing Machinery.

Military Use of Terrain

"... and meanwhile learn the nature of the land, how steep the mountains are, how the valleys debouch, where the plains lie, and understand the nature of rivers and swamps... it is this which teaches how to find the enemy, take up quarters, lead armies, plan battles and lay siege to towns with advantage." (*Machiavelli, 1513*) This quotation is used to introduce the theme of a 200-page state-of-the-art survey, "Earth Science Applied to Military Use of Natural Terrain," (*AFCRL-69-0364*), edited and largely written by Stanley M. Needleman of the Terrestrial Sciences Laboratory. The report reviews the earth's terrains in the context of military operations—natural landing areas for aircraft, site selection for operational facilities, and ground force deployment. It also discusses the variations of soil materials as a function of weather and climate.

Figure 1. A survey of the state of the art in the evaluation of the natural terrain by earth-science techniques and measurements systems is presented in response to a need existing for many years. This report considers the terrain as an envelope of the environment and all related parameters that are basic in an evaluation for relevant applications.

Mr. Needleman summarizes the various remote-sensing methods as well as on-site methods for analyzing soil and terrain properties. He then introduces the concept of incorporating sensors of all types into airborne or satellite systems that would produce imagery-giving properties of different terrains all over the world. The appendix contains a proposed matrix coding system of digitized terrain parameters in designator groups which describe simple or complex terrain conditions relative to the specific terrain use in military operations. It further proposes an optimum remote-sensing system based on instrumentation currently available or under development. The report is of immediate benefit to DOD operational agencies. It is of potential value to all research scientists in geology and those involved in studies of techniques and instrumentation for the remote sensing of terrain. The report contains a glossary and an extensive bibliography.

Stanley M. Needleman is the author of "Military Use of Terrain" which surveys all current methods of remote sensing of terrain.

Mr. Stanley M. Needleman has been a geologist in the Geotechnics Branch of the Terrestrial Sciences Laboratory at AFCRL since 1966. He is currently performing theoretical and experimental laboratory and field investigations of geological micromorphic features of landforms in a coastal environment. A five-year field test program will include sampling and analysis of landform materials, mapping and surveying of grid and radial patterns of the features, correlation of ground data and airborne imagery in selected sensor bandwidths, and reduction of data for publication. Major emphasis will be on the installation and refinement of an airborne terrain-profiling recording device for precise measurement of microrelief parameters and topographic control points.

Mr. Needleman has a B.A. (1949) and an M.A. (1950) in Geology from Boston University. He is a member of the American Association for the Advancement of Science, RESA, Explorers Club, American Polar Society, Society of American Military Engineers, American Geological Institute, and the Air Force Management Association. He has published many articles reporting the results of his research since 1956.

Solar Elevation, Depression and Azimuth Graphs

A series of several hundred graphs that permit the user to quickly—within two or three minutes—compute the angle of elevation or depression and the true azimuth of the sun to an accuracy of 1° at any latitude, altitude, and time of year has been prepared and published by AFCRL. These graphs are contained in a 300-page report, "Solar Elevation, Depression and Azimuth Graphs," (*AFCRL-70-0086*) by Captain Lawrence R. Doan and Brian P. Sandford of the Optical Physics Laboratory. The report contains explanations and examples. With the aid of the Nautical or Air Almanac, it can also be used to find elevation or depression and azimuth of any heavenly body whose declination is less than 30°.

A smaller companion report, "Graphs of the Solar Depression Angle from 0 to 32° vs Local Hour Angle for Latitudes 0 to 90°," (*AFCRL-69-0543*), enables solar depression to be determined rapidly with higher accuracy for rising, setting, and twilight phenomena.

Several examples of problems that the graphs will help the experimenter solve are:

1. Determine the solar elevation or depression angle and the solar true azimuth for any time of year and for any location on earth.
2. Determine the range of solar zenith angles during any day of the year for any location on earth.
3. Determine the local time of rising and setting and the rising and setting azimuths of the sun, moon, and planets, including atmospheric refractive effects, for any altitude of the observer.
4. Determine whether a particular point in the earth's atmosphere is in sunlight or darkness at any time of year.

The graphs for computing answers are far less voluminous, easier to use, and include more information than previous standards for making these computations.

Captain Lawrence R. Doan (left) and Brian P. Sandford have recently compiled a series of graphs which can be used to derive solar elevation, depression, and azimuth without the need for detailed calculations.

Captain Lawrence R. Doan is a general physicist in AFCRL's Optical Physics Laboratory. He is contract monitor for the development of the OPTIR computer code, a code designed to predict the atmospheric infrared emissions resulting from nuclear detonations. He also assists in the reduction of data taken aboard AFCRL's KC-135 flying laboratory.

Captain Doan received a B.S. in Chemistry and Physics in 1960 from Louisiana State University. Following his undergraduate study, he entered the University of Michigan graduate school under an AFIT study program and received an M.S. in Physics and an M.S. in Aeronautics and Astronautics in 1962.

Before joining AFCRL, Captain Doan was assigned to the Air Force Weapons Laboratory where he conducted research on the electromagnetic blackout effects of nuclear weapons, and to the Arms Control and Disarmament Agency where he was concerned with the detection of clandestine nuclear detonations.

Mr. Brian P. Sandford has been a research physicist in the Radiation Effects Branch of the Optical Physics Laboratory at AFCRL since 1968. He is currently developing a program of spectroscopic infrared and visible region auroral and airglow research to understand the atmospheric chemistry responsible for the observed phenomena. He also manages the visible region and near infrared airborne equipment program for Mighty Sky.

Mr. Sandford received a B.S. in 1956 and an M.S. with First Class Honors in Physics in 1958 from Victoria University, Wellington, New Zealand. In 1969, Queen Elizabeth II presented him with the Polar Medal Award in recognition of his services and atmospheric research in the Antarctica.

Mr. Sandford is a member of the Institute of Physics and the Physical Society, the New Zealand Antarctica Society, and the International Union of Geodesy and Geophysics. He has published many articles on his research.

Readers Interchange

It is hoped that the Readers Interchange, under the columns headed "Research Needs" and "Speculative Ideas," will encourage reader participation in suggesting further basic research for the scientist that will lead to new product development for the engineer. As a further source of reader participation, the answers to question 2 of the tear-out page, "Comments to the Editor," of this issue, may be published in the Readers Interchange of a subsequent issue (with the permission of the reader).

On the other hand, the column headed "Research Advances," which contains materials furnished by our own research laboratories, and the items in the column headed "Invention Disclosures," which are selected from current invention disclosures originally submitted for possible patent applications, but now released from such action,* may suggest further research for our readers.

Reports of actions stimulated by the Readers Interchange or suggestions for its improvement are welcome.

Director of Laboratories, AFSC/DL
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**For a more detailed discussion, see "Project: Use It" by Lt Col Ludwig Lippert, Staff Judge Advocate, in the OAR Research Review, Vol. IX, No. 3, May-June 1970.*

research advances

A New Infrared Laser Modulation Crystal

Development: High-quality CuCl crystals, grown as clear regular tetrahedrons up to 8 mm on edge by a new AFCRL technique (patent pending), with optical transparency beyond 20 microns. Pulse code modulation should be achievable in the infrared out to at least 18 microns. CuCl is a I-VII semiconductor and its crystals operate in the transverse mode.

Applications: May be applicable to communication systems using CO_2 lasers.

AFCRL/CRWB Project No. 5620 Coupling Report No. AFCRL 70-8

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AUTOVON 487-4956

Solid State Intervalometer

Development: A solid state intervalometer prototype utilizing transistors and integrated circuit logic has been designed and fabricated. The intervalometer was designed to satisfy the need for a sophisticated device combining the best components and techniques available to acquire the following capabilities:

1. Cockpit selectivity of a specific MER/TER station
2. Cockpit monitor of bombs-away
3. Ability to select and control various time release intervals from cockpit
4. Prevent weapon release malfunctions such as hung bombs that cause bomb collisions.

This solid state intervalometer will be an improvement over existing electro-mechanical types which are limited in response time and selectivity and which cannot be controlled from the cockpit.

Applications: The intervalometer will interface with future weapon release systems as the stores management sets for the B1A, F-15, and AX aircraft.

This prototype will be utilized to evaluate techniques such as integrated circuitry and other solid state devices to control, direct, and monitor weapon release pulses of very short durations and intervals.

Tests will also be performed to determine if the low signal level integrated devices will survive in an electronic transient environment such as that which exists during carriage and deployment of conventional ordnance.

RA AFAL-71-1

research needs

Lasers

Areas of Need:

1. A better understanding and a means for the alleviation of the mechanism of damage to ruby and Nd: YAG laser rods resulting from high power loading.
2. High quality laser rod material for lasing in the 2 to 5 micrometer wavelength region.
3. Modulator materials with improved drive voltage, transparency, low-temperature environment, and damage level characteristics.
4. Nonlinear optical materials with optimum linear coefficients, high homogeneity, high damage levels, and low absorption at operating and pump frequencies (less than 0.001 cm^{-1} absorption coefficient).
5. Efficient photodetectors in the 3 to 5 micrometer region and at the 10.6 micrometer line that will operate at room temperature and at nanosecond response times. Develop the ability to grow HgCdTe crystals.
6. Holographic recording materials with good erase/rewrite capability and short film processing times, high sensitivity, and good diffraction characteristics.

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RN AFAL-70-3

Capillary Matrix for Fuel Cell

Problem: Electrochemical fuel cells depend on the capillary potential of a porous material (matrix) to hold the electrolyte between the electrodes. Alkaline electrolyte (potassium hydroxide) capillary matrix fuel cells now use either asbestors fiber mats or pressed potassium titanate mats. Asbestos matrices have high capillary potential, ensuring good electrolyte retention, but degrade chemically in hot potassium hydroxide; potassium titanate is chemically stable, but has low capillary potential. Mixtures of asbestos and potassium titanate have usually resulted in a compromise, with some of the good and bad features of both.

Area of Need: Development of more stable matrices with high capillary potential that will not increase electrochemical polarization losses and that will be able to reach lifetimes of 10,000 hours for use in Air Force communications satellites.

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RN AFAPL-71-6

Advanced Energy Sources for Crew Escape Systems

Problem: Crew escape systems now depend for their initiation on the burning of solid fuel propellants in gas generators, catapults, and rocket catapults. Delayed ignition, erratic burning of the propellant, and fracturing of propellants have reduced reliability and confidence in their performance. The resulting deviation from the design thrust-time characteristics can cause an unacceptable escape system trajectory as well as a delayed ejection.

Area of Need: New non-burning energy sources are needed for high reliability crew escape systems.

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RN AFFDL-71-3

Boundary Layer Properties Preceding Separation

Problem: Experiments indicate a region of increasing surface pressure (up to ½ ft long in a wind tunnel) upstream of the point where the wall shear goes to zero; the pressure appears to be due to an attached boundary layer of a type not treated by conventional boundary layer methods. The surface area affected by the increasing pressure region, as well as the separation region pressure, must be known to predict the separation point.

Area of Need: More research is needed on the prediction of laminar boundary layer separation induced by rocket exhaust plumes.

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RN AFFDL-71-6

Pressure Sources Employing Thermal Input Power and No Moving Parts

Problem: Conventional thermodynamic refrigerators depend on a mechanical device to act as the prime mover and/or compressor of an oscillating or steady-flow source of gas having pressure capability from 1.7:1 to 200:1. However, sophisticated electronic spaceborne systems require dependable, long-life (50,000 hours or more) cooling systems, including systems operating at cryogenic temperatures.

Area of Need: Replacement of costly mechanical systems by one with no moving parts. The pulse tube and the Joule-Thomson orifice are examples of possible refrigerating expansion devices that could be coupled to a no-moving-parts compressor.

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RN AFFDL-71-11

Data Requirements for Advanced Compressor Design

Advancement of this research will accelerate technology incorporation of higher flow per frontal area, higher pressure ratio per stage, and improved stability fans and compressors into the Air Force inventory of turbojets and turbofans for subsonic, transonic/supersonic, high Mach, and special engine propulsion systems.

Problems and Areas of Need: Research needs can be divided into the following areas:

1. High Mach Number, High Stage Loading (for LP Compressors). Methods to reduce losses resulting from the combined effects of shock waves and high diffusion in compressors by (a) refinements to the basic compressor geometry, (b) special devices to effect boundary layer control, (c) improved analysis techniques for design control.

2. High Mach Number, Low Stage Loading (for Fan Tips). High-bypass-ratio fans require fan operation at high tip speed to keep turbine weight low, resulting in light blade loading with a high Mach number at the fan tip. Shock losses become a large part of the energy addition, thus reducing efficiency. Improvement of techniques and data for designing compressor rotors with very low shock losses are needed.

3. Transonic Mach Number, High Stage Loading (for Fan Roots). Because of the inherently low wheel speed in the root section of low and high bypass fan blades, it has been difficult to obtain high pressure rise in that section. Currently, a uniform pressure profile has been obtained from the fan by high turning (high loading) and the addition of booster stages. Increasing the loading capability through improved blade profiles, blade cambers, and sealing of the hub cavities should be explored.

4. Systematic High-Performance Design Data. To replace empirical NACA data modified by "experience factors" to account for changes at high levels of loading and Mach number, a transonic and supersonic cascade data bank must be established. This data bank must be based on systematic experiments at high diffusion factors and Mach numbers to provide a better definition of the design loss coefficients and deviation angles, and off-design characteristics.

5. Instrumentation for Flow Within Rotors. The assumptions made in compressor design systems for the development of losses and deviation angles within the blade row cannot be confirmed until instrumentation is developed to measure accurately the flow conditions within an operating high-speed rotor. The laser velocimeter shows promise, but an instrument is required to map the entire flow field. High frequency, miniaturized instrumentation is also being used.

6. Three-Dimensional Analysis Techniques. Present compressor design techniques are quasi-3-dimensional calculations, with adjustments for the real variations in the third dimension. Analysis techniques are needed for calculating the complete 3-dimensional flow field within a compressor to permit design optimization. Such analysis must at least consider compressiblity and shock waves; inclusion of viscous effects are desirable.

7. Secondary Flow Effects. Until recently, secondary flow effects were considered negligible. However, evidence now exists suggesting that secondary flow effects can trigger boundary layer separation, stall, and other transient compressor behavior. Further empirical and analytical study of these phenomena are therefore needed.

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RN AFAPL-71-1

Aircraft Noise Abatement

Problem: Engine noise of the larger and more powerful propulsion systems must be reduced to provide a safer working environment for ground and flight crews, to improve the general community environment around military bases, to alleviate the problem of acoustically induced structural fatigue, and to reduce the possibility of aural detection during combat operations. To achieve a low noise level without sacrificing high performance and without increasing weight requires continued research into the basic mechanisms of noise generation, with particular emphasis on primary jet noise production.

The lack of clear theoretical understanding of the mechanisms of jet noise production as well as the lack of revealing experimental techniques have severely hampered the development of effective jet noise suppression techniques. Past efforts in the area of jet noise suppression have been guided more by intuition than by specific scientific principles.

Areas of Need:

1. A program to determine the intensity, directivity, and spectrum of far field jet noise as a function of the mean flow parameters, the turbulent structures in the mixing zones, and other fluctuating quantities in the jet flow for such jet configurations as:

   a. Coaxial jets with operating conditions typical of STOL transport propulsion systems (low velocity, high mass flow);

   b. Supersonic jets with operating conditions typical of SST transport and long-range strategic propulsion systems (high velocity, high temperature flow).

2. Advanced measurement techniques and instrumentation for:

   a. Miniature transducers to measure fluctuating pressures

   b. Hot wire anemometry

   c. Optical methods (cross-beam laser techniques, laser interferometer, etc.)

   d. Holography

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RN AFAPL-71-3

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- Aerospace Instrumentation Laboratory — J/F-4, M/A-30, M/J-15, S/O-7, S/O-15, S/O-16, N/D-15
- Data Sciences Laboratory — M/J-24, N/D-8
- Ionospheric Physics Laboratory — M/A-38, M/J-33, J/A-11, J/A-19, N/D-6
- Meteorology Laboratory — J/A-23, J/A-30
- Microwave Physics Laboratory — J/F-2, J/F-34, M/A-37, J/A-1, J/A-31, S/O-14, N/D-16, N/D-17
- Optical Physics Laboratory — J/F-20, M/J-23, S/O-9, N/D-17
- Sacramento Peak Observatory — J/F-7, S/O-20
- Solid State Sciences Laboratory — M/A-35, S/O-11, S/O-12
- Space Physics Laboratory — M/A-33, M/J-31, M/J-32, J/A-22, N/D-4, N/D-14
- Terrestrial Sciences Laboratory — M/A-31, S/O-3, N/D-17

Air Force Office of Scientific Research
- Directorate of Chemical Sciences — N/D-1
- Directorate of Engineering Sciences — M/J-1
- Directorate of Life Sciences — J/F-30, S/O-17
- Directorate of Mathematical and Information Sciences — J/F-19, M/A-23
- Directorate of Physics — J/F-25, M/J-7
- Executive Director — J/A-6

Aerospace Research Laboratories
- Chemistry Research Laboratory — M/A-13, M/A-20
- Energetics Research Laboratory — J/A-29
- Fluid Dynamics Facilities Research Laboratory — M/A-24, J/A-4
- General Physics Research Laboratory — J/F-11, M/A-9
- Hypersonic Research Laboratory — J/F-5, M/J-16, N/D-10
- Plasma Physics Research Laboratory — M/J-13, J/A-28
- Metallurgy and Ceramics Research Laboratories — J/A-14, J/A-26
- Solid State Physics Research Laboratory — M/A-15, M/J-4, S/O-1
- Thermomechanics Research Laboratory — M/A-4, S/O-4

Boston University*
- Physics Department — J/F-26

European Office of Aerospace Research — J/F-31, M/A-7, M/J-29

The Frank J. Seiler Research Laboratory
- Aerospace Mechanics Directorate — J/F-24, M/J-26

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- Department of Chemistry — S/O-8

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Department of Mechanical Engineering	J/A-2
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Office of Aerospace Research	
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Staff Judge Advocate	M/J-35
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Rice University*	
Department of Mechanical and Aerospace Engineering and Materials Sciences	J/F-19
Systems Research Laboratories, Inc.**	M/A-4, M/J-22, J/A-26
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University of Adelaide, South Australia*	
Department of Physics	J/F-21
University of Dayton**	
Research Institute	J/A-12
University of California*	
School of Engineering and Applied Science	J/A-10
The University of Rochester*	
Physics Department	M/A-17
University of Toronto, Canada**	
Department of Metallurgy	J/A-14
Williams College*	
Physics Department	M/J-19

**Supported wholly or partly by Air Force Office of Scientific Research.*

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Part 4. Readers Interchange

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Requests from institutions and individuals for further information may be either mailed to the addresses below, or telephoned to the individuals named as "Contact" at the end of each article. If no organization follows the name of the contact, assume that it is the same organization given under the title of the article.

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861-4441 + Ext.
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